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ESDCD news

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Earth and Space Data Computing Division

Earth Sciences Directorate, Goddard Space Flight Center

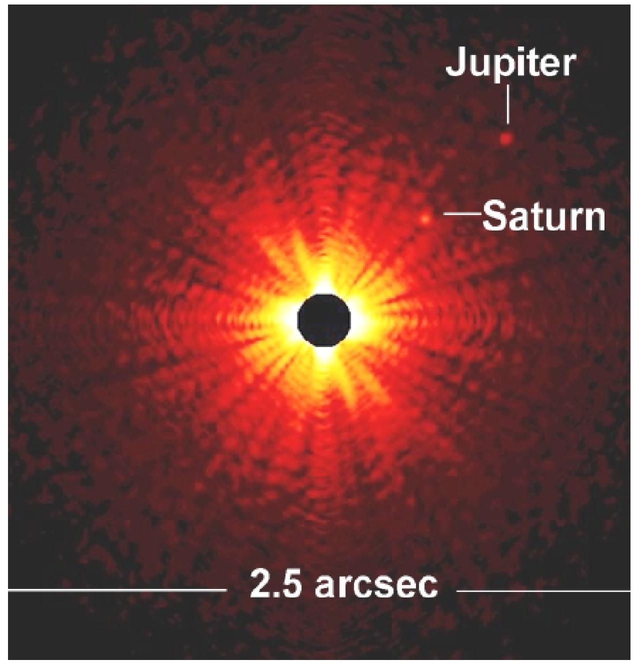
In This Issue

Computational Optics

In Search of Other Worlds

Richard Lyon's notable research and development in computational optics at the ESDCD in the 1990's helped to deduce the error in the Hubble Space Telescope and to determine the prescription with enough fidelity to correct the telescope. This ultimately corrected the blurry images captured by Hubble's original flawed telescope, restoring the instrument's usability until it could be repaired. A central part of NASA's Origins Program, Hubble and its near-term follow-ons—the Space Infrared Telescope Facility and the James Webb Space Telescope—will help us determine the nature and history of our solar system.

The next generation of NASA's space science missions will leverage the explosion of multidisciplinary scientific tools being developed today. Lyon is developing unconventional tools in imaging interferometry and coronagraphy to help these future missions deepen our understanding of the universe and our planetary neighbors. Supporting this development has been ESDCD's Medusa cluster 128-processor (1.2 GHz Athlon MP), which Lyon has used in his research in optical modeling and control systems, and he also plans to utilize the Thunderhead cluster 512-processor (2.4 GHz Pentium 4 Xeon) in the future.



Extrasolar Planetary Imaging Coronagraph (EPIC) simulated image of the Sun, Jupiter, and Saturn as seen from approximately 33 light-years. EPIC will search for gas giant planets around stars up to 114 light-years away from the Sun. Image credit: Richard Lyon, GSFC

One of the central themes of NASA's Origins Program is being able to detect, image, and characterize planets, particularly those that have characteristics of terrestrial (Earth-like) and jovian (Jupiter-like) planets, around nearby stars. This requires both high-resolution imaging (implying large space telescopes) and high-contrast imaging (requiring the use of coronagraphy and/or nulling), an optics technique being developed by Lyon. A coronagraph is a device that allows for imaging of a very dim object, such as a planet, at very close angular resolution, to a bright object, such as a central star. Coronagraphs enable direct detection of extra-solar planets by tapering the diffraction of light from a star and subsequently removing it. Nulling uses destructive interference to cancel the starlight, allowing only the planets' light to be detected.

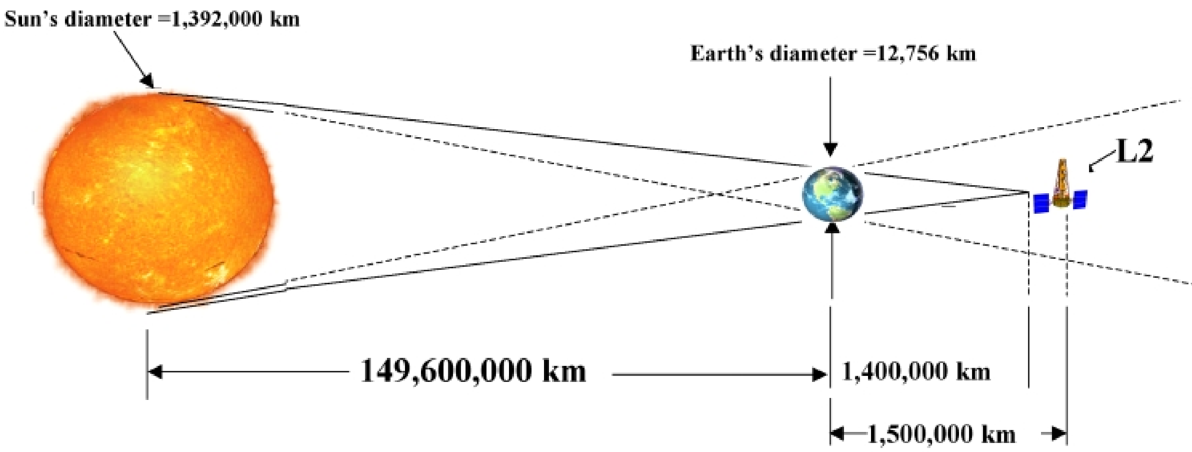
NASA envisions that within the next 50 years we should be able to resolve 1,000-km structures on detected Earth-like planets as part of NASA's search for the precursors to life. This would require telescopes on the order of tens to hundreds of kilometers in diameter, ". . . an impossible task with conventional telescope technology," states Lyon. That is why Lyon is developing imaging interferometry, a method of synthesizing a larger aperture telescope in space by using an array of smaller telescopes spread out over a distance. Optically "phasing" multiple telescopes that are flying in formation is a very tough proposition; however, according to Lyon, it is the only approach remaining for ultra-high resolution imaging in the space sciences.

Over the past 5 years, Lyon has significantly advanced the state of the art. Based on his intensive research, resulting in 22 technology papers in 2003 alone, Lyon has been funded to build an incremental series of testbeds and a ground instrument. Currently located both at GSFC and at Harvard, these testbeds further the development of the techniques in laboratory settings. The testbeds play an important role in validating Lyon's models, which ultimately will be used to design proposed flight systems.

Lyon has also been developing a coronagraphic nulling approach for the Extrasolar Planetary Imaging Coronagraph (EPIC) Mission. EPIC, which will be proposed in an upcoming Discovery Announcement of Opportunity, was named in honor of Epicurus, who in 300 BC was the first to postulate that points of light in the sky might be other worlds. EPIC will search for gas giant planets around stars up to 114 light-years away from the Sun and will investigate the occurrence of these planets as well as their orbits and atmospheric composition. This joint NASA mission with GSFC, Harvard, and JPL investigators will use coronagraphic techniques for direct imaging of jovian planets around the nearest ~200 stellar sources. "We have the technology to do this mission today," says Lyon. Indeed, the study of coronagraphic approaches requires the supercomputing technology of ESDCD, since it incorporates highly detailed diffraction, vector diffraction, and electromagnetic computational models to simulate and optimize various approaches.

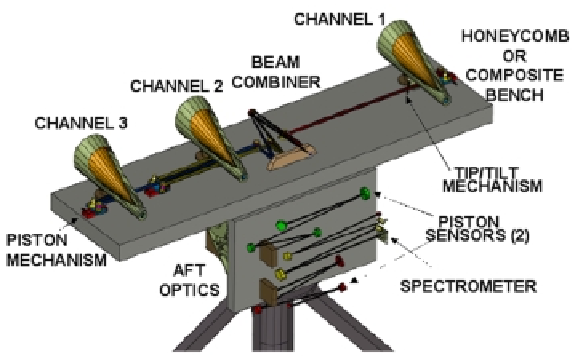
Terrestrial Planet Finder (TPF) is a major mission by NASA's Origins program to detect Earth-like planets and examine "biomarkers," currently believed to be the necessary spectral components for the potential for life. "If we find giant Jupiter-like gas planets using EPIC, we are more likely to find an Earth-type planet nearby," says Lyon. NASA plans to narrow the list of approximately 600 candidate planets that can be examined by a flight mission to about 200. Ultimately TPF will focus on a limited subset for in-depth spectral characterization of the biomarkers. Lyon is conducting a 3-year study of coronagraphic techniques applicable to TPF.

Lyon is also researching the use of imaging interferometry for Earth science missions such as the Earth Atmospheric Solar-Occultation Imager (EASI), a NASA mission concept under study at GSFC. EASI would consist of five small telescopes on an 8-meter-long platform that looks back at the Earth from the Earth-Sun L_2 Lagrangian point. From this vantage point, 1.5 million kilometers from the Earth away from the Sun, EASI would image the Earth's limb vignetted against the Sun to obtain a complete 3-D hyperspectral image of the atmosphere every 24 hours at 1-km resolution. This would enable scientists to study atmospheric water vapor, methane, carbon dioxide, molecular oxygen, ozone, and nitrous oxide lines in 1- to 5-micron spectral bands for the entire Earth. Lyon's use of the ESDCD's clus-



L_2 observations of the Earth's atmosphere using solar occultation. Image credit: Richard Lyon, GSFC ter computers has been instrumental to this modeling, systems design, large-scale simulation, and algorithm design for imaging interferometers.

Lyon and Jay Herman of GSFC's Atmospheric Chemistry and Dynamics Branch were awarded funding to develop the Solar Viewing Interferometry Prototype (SVIP), a ground instrument, to study technologies for the EASI mission. SVIP is a three-telescope Fizeau interferometer and is the first instrument of its kind. SVIP will perform spectroscopy of Earth's atmosphere in the near infrared while simultaneously correcting for atmospheric turbulence with a real-time active optical control system. After laboratory testing followed by operations on a mountaintop, SVIP could ideally be deployed as a balloon-borne mission at 70,000 feet.



Solar Viewing Interferometry Prototype (SVIP). Image credit: Richard Lyon, GSFC

Lyon is also involved in NASA's recently funded Stellar Imager (SI) Vision Mission Study. SI is a mission proposed for the 2020 to 2025 time frame to directly image Sun-like stars to model the evolution of the Sun over 10 billion years as well as understand its underlying dynamo activity. Ultimately, this mission will work with other NASA missions, including those above, to provide views of other solar systems and an understanding of the Sun's impact on the habitability of planets.

SI will require an array of actively controlled telescopes, flying in formation, distributed over 500 meters. Combining the multiple telescope beams achieves a synthetic telescope with an aperture of 500 meters, able to resolve the stellar disks of nearby stars and achieve unprecedented resolution. In order to facilitate the complex technologies, Lyon and his GSFC team are developing the Fizeau Interferometry Testbed (FIT) in a laboratory setting. The first phase of FIT is nearly complete and will soon be demonstrating closed-loop control of a 7-aperture interferometer testbed.

Scientific Visualization Studio

SVS Scores Big Touchdown!

A Scientific Visualization Studio (SVS) high-definition digital zoom aired nationwide on CBS for the the NFL's Super Bowl XXXVIII pregame opener on February 1, 2004. The zoom from Earth to space starting on the football field in Houston's Reliant Stadium accompanied a tribute to the crew of NASA's Space Shuttle Columbia.

The SVS seamlessly composited together datasets of the Earth from NASA's fleet of Earth observing satellites, including the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on Terra and Aqua, with resolutions from 8,000 to 250 meters; and Landsat-7 images of the U.S. to 15 meters. They also incorporated images of the ground from commercial spacecraft IKONOS to 1 meter and Quickbird to 0.6 meters. The seamless zoom also incorporated an authentic starfield from the Hipparcos Star Catalog and field designs and logos from Reliant Stadium and the National Football League.

Reliant Stadium with Super Bowl field and stands in view. Image credit: NASA SVS; Digital Globe/Quickbird; Space Imaging/IKONOS; MODIS Rapid Response Team, NASA/GSFC

A related Web article, "One Looooong Pass—NASA Drops in on the Big Game," ran as a GSFC Top Story on February 1, 2004.
http://www.gsfc.nasa.gov/superzoom.html
http://svs.gsfc.nasa.gov/vis/a000000/a002800/a002887/

SVS "Zoom" Visualizers Selected for I.D. Fifty

In celebration of International Design (I.D.) Magazine's 50th anniversary, I.D. selected designers from every State in the U.S. to "show how local landscapes incubate creativity and how local materials have emotional, not just economic, power." I.D. is a leading critical magazine covering the art, business, and culture of design. Horace Mitchell, Visualization Manager, and Greg Shirah, a computer scientist and visualization expert, were chosen to represent Maryland, receiving a full page in the January/February 2004 edition. Mitchell and Shirah lead production of the SVS's awe-inspiring zooms using Earth and space data captured by satellites and other sources. The zooms are all available to the public on the SVS Web site.

http://svs.gsfc.nasa.gov/search/Keywords/Zoom.html
http://www.idonline.com

Digital Earth PC Prototype

The SVS has been awarded $250,000 per year over the next 2 years to continue development of the Digital Earth PC prototype. NASA Ames Research Center's (ARC) Learning Technologies Project (LTP) is funding this project to help display and disseminate NASA's vast collection of data.

In the first year, this project involved porting a range of capabilities of the SVS's Digital Earth Workbench software to a PC to enable viewing of geospatial data in relationship to its location on the Earth. The system allows viewing of both animations and still images in near-real time on a virtual globe. A user of the system can pan across or zoom into the imagery at any scale, and images can be stacked to show data correlations.

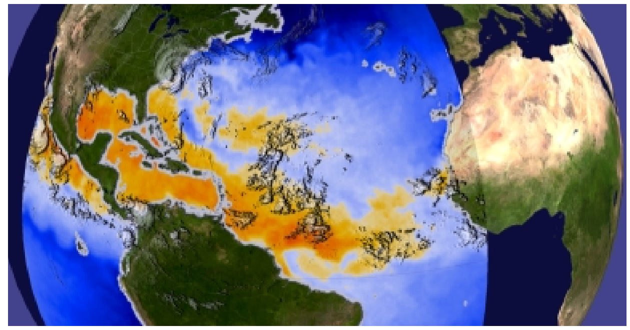
During the next 2 years, this project will develop servers and protocols to deliver NASA content to such geospatial data viewers.

The primary use of the Digital Earth PC is to showcase NASA imagery, such as SVS animations, in a global context, with schools nationwide as the target audience. The system is also useful to scientists and researchers as well as the general public.

The system connects via the Internet to databases of high-resolution images using the Web Mapping Service (WMS). The WMS is an open source data transport protocol developed by the Open GIS Consortium. Accessible image collections currently include the Jet Propulsion Laboratory's Landsat image server and the Global Learning and Observations to Benefit the Environment (GLOBE) Program's Earth data visualization system.

Retrieved data are displayed in a viewer in the context of their geospatial location on the Earth. Horace Mitchell, Visualization Manager, leads theproject. Eric Sokolowsky, a computer scientist-visualizer of GST, has been developing the viewer. Mitchell and Sokolowsky demonstrated the system at ARC in mid-September 2003. LTP awarded the follow-on funding in October 2003.

http://svs.gsfc.nasa.gov/vis/a000000/a002800/a002824/index.html



This visualization shows the cold water trails left by Hurricanes Fabian and Isabel. The red/orange/blue colors represent ocean temperatures (red/orange is 82 degrees F and higher). As the hurricanes move through the ocean, they each leave a wake of cold water as they draw energy from the warm ocean. Datasets: sea surface temperature from Aqua/AMSR-E; cloud imagery from GOES/IR4; land imagery from GSFC's "Blue Marble," a dataset composited mostly from MODIS data. Image Credit: SVS

Computational Technologies Project

Building Better Earthquake Forecasts

Buildings collapsed and mountains reportedly grew a foot in a magnitude 6.5 earthquake near San Simeon, California, last December. On average, the state loses $2 billion per year to earthquakes—half of the losses for the entire U.S. While predicting the exact date that an earthquake will hit is a distant prospect, techniques being developed by the QuakeSim investigation show significant potential for forecasting earthquake locations in California.

"We are trying to understand how earthquake fault systems interact so we can improve the forecast maps by a factor of 10 in both space and time," said QuakeSim principal investigator Andrea Donnellan, a NASA Jet Propulsion Laboratory (JPL) geophysicist and deputy manager of the Earth and Space Sciences Division. "We want to help communities make buildings safer and reduce the destruction from earthquakes."

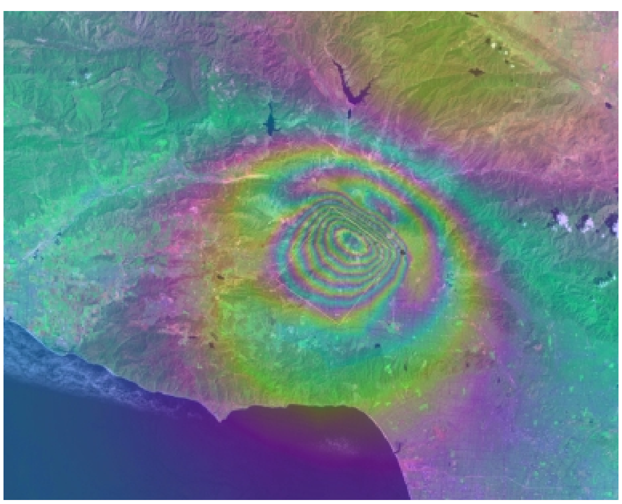
Guiding the QuakeSim effort are ground and space-based observations. The team concentrates on southern California, "the best-instrumented area in the world," Donnellan said. Over 300 seismograph stations measure seismic waves inside the planet, and 250 Global Positioning System (GPS) stations can be pinpointed by satellites to within 1 millimeter. Another observation technology with millimeter-level precision is Interferometric Synthetic Aperture Radar (InSAR), where a radar satellite records ground movements through timed snapshots of a spot on Earth.

Observations, especially from InSAR, can be used to infer how stress is being transferred between faults and show where faults are more active. While observations are essential, “we can't measure stress and strain at all points of space and time, so we use a computer as a laboratory,” said QuakeSim co-investigator John Rundle, professor and founding director, Computational Science and Engineering Center, University of California, Davis.

QuakeSim's software tools are designed to match observations in capturing earthquake processes at tiny scales. A major tool is PARK, a boundary element software code fine tuned for studying unstable slip on the highly active Parkfield segment of the San Andreas Fault. For modeling larger swaths of California, the team turns to GeoFEST and Virtual California.

GeoFEST is software developed by JPL that simulates how the planet surface deforms right after earthquakes and how subterranean stress accumulates over time. In a finite approach, the software divides southern California into millions of elements. GeoFEST can model all the fault types (such as thrust and vertical strike-slip) of arbitrary orientations.

The team has used GeoFEST to simulate 500 years of surface deformation caused by two large southern California earthquakes: Landers (magnitude 7.3) in 1992 and Northridge (magnitude 6.7) in 1994. The output is simulated InSAR data, visualized in rainbow-colored “fringes” indicating 6.35 centimeters of ground motion. The Northridge simulation shows nearby mountains growing 38.1 centimeters because of the earthquake and then 12.7 more centimeters over the next 2 years. Intriguingly, this additional growth has little to do with aftershocks but is due primarily to inter-earthquake “quiet” ground motions. Such quiet motions can either accumulate enough strain to spur an earthquake or may quietly relieve strain without earthquakes.



A snapshot from a GeoFEST simulation of surface deformation captures terrain displacement 500 years after 1994's Northridge, California, earthquake. Each color fringe represents 6.35 centimeters of ground motion. Image credit: NASA JPL

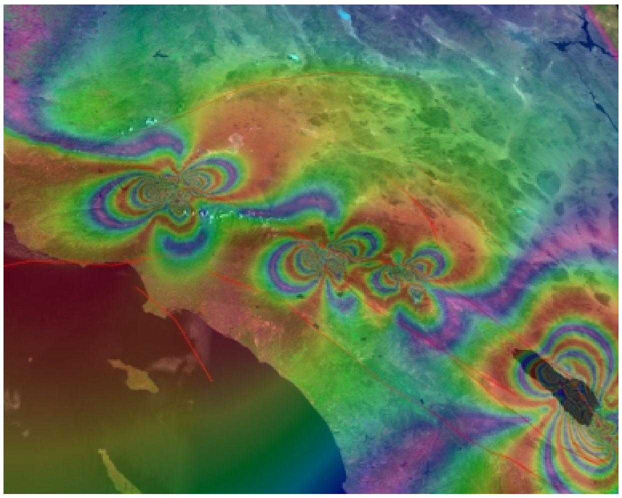
GeoFEST's versatility in representing faults is enabling close examination of the Los Angeles Basin. “From GPS, we have learned that the northern LA Basin is being squeezed from downtown LA in the south to the San Gabriel Mountains in the north,” Donnellan said. This squeezing raises and concentrates stress in the north. The faults there are inherently weak, as shown by seismology and space-based observations of surface deformation. “Because they are weaker, the faults strain more than the surrounding areas,” she said.

Virtual California is a realistic computer simulation of the dynamics of southern California earthquake faults, explained Rundle, the software's creator. Calculations begin with the historic earthquake record in southern California over the last 200 years. Incorporating these data, Virtual California puts friction on faults and simulates how 650 fault segments affect each other.

The next step is “pattern recognition, winnowing down all the possible locations where earthquakes could occur,” Rundle said. QuakeSim's “Pattern Informatics” method uses the Southern California Earthquake Catalog, which records seismographic information for earthquakes of magnitude 3 or greater since 1932, to identify “hot spots” where large earthquakes are likely to occur during the years 2000 to 2010. As of this writing, earthquake probabilities are computed in 3,000 zones, 10-kilometer-wide “bins spread like a tile floor across the state,” he said. The result is a forecast map showing locations where events of magnitude 5 or greater are probable. An earlier 10-year forecast correctly located 6 earthquakes to within 11 kilometers, including 3 events within 6 months of the paper appearing in the Proceedings of the National Academy of Sciences in February 2002.

Newer Virtual California simulations look 1,000 years forward in time. Similar to GeoFEST, visualizations of their output show simulated InSAR

fringes, in this case marking ground movement in multiples of the 5.7-centimeter radar wavelength. In an animated version, rainbow-hued butterflies repeatedly explode from the faults. The larger the butterfly, the larger the corresponding earthquake, and several are gigantic, covering large areas of California.
These recent simulations show that earthquakes cluster in time and space because of interacting faults. “A fault can raise or lower the stress on related and entirely different faults,” Rundle said. “Earthquakes on some faults trigger earthquakes on other faults. They can also shut down activity on 'third-party' faults.” Similar earthquake clustering and less frequent large events are observed both in the geological earthquake record and in the historic activity recorded after the great 1906 San Francisco earthquake.



Four butterfly-like structures indicate earthquakes in a Virtual California simulation forecasting 1,000 years of earthquakes in southern California. Butterfly size corresponds to earthquake size, with each color fringe marking 5.7 centimeters of ground movement. Image credit: NASA JPL

An ongoing application study is ascertaining whether two groups of faults “phase-lock” together: one group is active while another is inactive. Although the LA Basin and the Mojave Desert in eastern California appear to be phase-locked, geophysicists dispute the matter. Another project is assisting the U.S. Geological Survey with their 30-year forecasts of damaging northern and southern California earthquakes (magnitude 7 or greater). Rundle has proposed replacing the current statistical technique based on fault failure times with a Virtual California-generated distribution of earthquakes.

For the Computational Technologies Project, part of QuakeSim's final milestone is a 5-year forecast of southern California earthquakes (magnitude 5 or greater) using enhanced versions of GeoFEST and Virtual California. Higher resolution is a significant aspect. In recent milestone runs on the ESDCD's Thunderhead Beowulf cluster, GeoFEST improved from 1,500 to 1.4 million elements. For Virtual California, the plan is to push from 3,000 to 300,000 zones. Coupling of these codes will exploit each software's strengths in representing particular earthquake processes.

Later this year, the entire QuakeSim software collection will be available through a Web portal. As Donnellan explained, “QuakeSim is completely general; the fault database is focused on southern California but is expected to expand to other regions in the future.” Thus, the earthquake community can apply the software to other regions, which need new capabilities to safeguard people and property. “In 40 to 50 years, one third of the world's population will live in seismically active zones,” Rundle said. “This problem is not going away—it is going to grow.”

http://ct.gsfc.nasa.gov

http://quakesim.jpl.nasa.gov

NCCS Highlights

NCCS Supports Aura Flight Planning

The Global Modeling and Assimilation Office (GMAO) recently provided data products to GSFC’s Atmospheric Chemistry and Dynamics Branch from the Data Assimilation System (DAS) operational assimilations and forecasts for Pre-Aura Validation Experiment (Pre-AVE) mission flight planning. The GMAO generated those data products on a dedicated SGI 3800 system run by the NCCS. Due to the flight schedule, the NCCS was required to ensure that the dedicated system remained operational at all times.

The Pre-AVE field campaign included airborne instrument flights in Texas and Costa Rica. DAS forecasts, including ozone forecasts, were integral in providing meteorological measurements and locations of atmospheric mission Areas of Interest so flight plans to those locations could be developed and executed. GMAO forecasts enhance mission success in locating meteorological phenomena of interest and in understanding the transport of gases and aerosols in the tropical troposphere and their exchange with the lower stratosphere.

Apple G5 Cluster at NCCS

The NCCS is investigating the suitability of using Apple G5 clusters for high-end computing. Apple Computers loaned a small 4-processor cluster running the OS X operating system to the NCCS. NASA's Office of Earth Science (OES) is hoping to partner its investigation with Virginia Tech, which recently acquired a 2,200-processor G5 cluster, and is actively seeking such partnerships. The small cluster at the NCCS enabled porting OES applications (e.g., ocean, climate, weather modeling, and assimilation) that may go onto the larger cluster at Virginia Tech.

Upgrades Benefit User Community

The NCCS user community reaped the benefits of the Mass Data Storage and Delivery System's (MDSDS) clustered configuration and newly upgraded tape drives during January and February 2004. The MDSDS's cluster configuration enabled significant software upgrades with only three 2-hour down-times. This minimal disruption enabled the NCCS to provide continued support to the monthly experimental research forecast runs of the NASA Seasonal-to-Interannual Prediction Project (NSIPP) Tier 1 coupled global ocean-atmosphere-land model and Tier 2 coupled land-atmosphere model, both of the GMAO. The clustered configuration also maximized users' access to MDSDS data immediately before and during the American Meteorological Society's annual meeting. Without the clustered configuration, the data would have been inaccessible for 48 hours.

In addition, the NCCS deployed 10 Storage Tek 9840C tape drives, which doubled the potential capacity of its existing 26,000+ 9840 tape media to 40 GB/cartridge, for .98 PiB* (1.1 PB) potential capacity. The new tape drives tripled the read/write speed to 30 MB per second.

The 9840C tape drives contributed to the ongoing transparent migration of legacy UniTree data into the MDSDS's SAM-QFS hierarchical storage management system. During January and February, more than 95 TiB (105 TB) of UniTree files were copied into the SAM-QFS system, for a total of more than 209 TiB (230 TB) legacy data processed, with approximately 78 TiB (86 TB) legacy data remaining. While supporting the data migration during this period, the MDSDS serviced more than 900,000 user file transfer requests.

*/*http://physics.nist.gov/cuu/Units/binary.html.*

New Backup Power Protection

In pursuit of bringing maximum power quality and system availability to its user community, the NCCS has installed new backup power protection, crucial in preventing vital data loss and equipment downtime. The new central 160 KVA Uninterruptible Power Supply (UPS), manufactured by Powerware, was installed on January 12, 2004, to provide 30 minutes of uninterrupted power to critical NCCS systems. The dual-cabinet battery bank also enables the UPS to remain operational during battery maintenance procedures. Critical loads connected to the UPS include an SGI Origin 3800 system, all alternative power supplies of the 14 TB Hitachi disk subsystem, all alternative power supplies of the SAM QFS mass storage system's Sun 15K system and Sun V880, the HP/Compaq SC45 management cabinet, and all GSFC Center Network Environment network routers and switches at the NCCS.

HP Disk Capacity Nearly Tripled

A study by the NCCS technical support team concluded that additional disk capacity was required to effectively support the input/output (I/O) system on the HP/Compaq SC45. I/O performance is critical to user satisfaction, program performance, and overall system efficiency.

After evaluating vendor proposals, the NCCS selected HP as the winning vendor and placed an order for more than 16 TB of disk storage, nearly tripling the overall disk capacity. The additional capacity also enhances the management of disk space and reduces downtime for disk management activities. This upgrade was completed in March.

DOD Acquisition Workshop

Thomas Clune of the NCCS attended a Department of Defense (DOD) workshop on the role of benchmarking in the acquisition of high-end computing platforms. By leveraging the coordination of the acquisition process for four separate computational facilities, DOD's Modernization Program has developed insightful metrics and analyses that could prove valuable to the NCCS's future high-end computing acquisitions.

How to Access NCCS Resources

To gain access to the computing resources of the NCCS, follow the instructions available at http://nccs.nasa.gov/resources/main.html.

NCCS User Services provides the NCCS user community with a wide variety of services including Help Desk support. The Help Desk is staffed Monday through Friday from 8 a.m. to 8 p.m. E.T., except for Federal holidays and GSFC closures. NCCS User Services may be contacted via telephone at 301-286-9120 or email at support@nccs.gsfc.nasa.gov.

Updates

Preparing for Third-Generation Internet

GSFC's Executive Council has awarded $500K for GSFC's Internal Research and Development (IRAD) proposal "Preparing Goddard for Large Scale Team Science in the 21st Century: Enabling an All Optical Goddard Network Cyberinfrastructure." The proposal was submitted by GSFC's Information Technology-Pathfinder Working Group (IT-PWG), with Patrick Gary of the ESDCD and Jeffrey Smith of the Applied Engineering and Technology Directorate (AETD) serving as co-principal investigators. Remaining IT-PWG members are serving as co-investigators.

The effort plans to establish a very high speed wide area connectivity, in this case using optical wavelength technology and 10 Gbps Ethernet per wavelength, from GSFC to the Scripps Institute of Oceanography through the University of California, San Diego, over the National Lambda Rail (NLR).

The NLR is a proposed next-generation national optical networking infrastructure that will provide a 1,000-times increase in speed of the current infrastructure to foster the advancement of research and network-based applications. The network will utilize dark fiber, unused cable laid in the ground at the height of the Internet boom. It will also be based on dense wave division multiplexing, which allows multiple channels of data to be transmitted at up to 200 Gbps on a single optical fiber.

The IT-PWG is chaired by Milton Halem, Distinguished Information Scientist, Emeritus, of GSFC's Earth Sciences Directorate (ESD). Members include Gary, Horace Mitchell, Ellen Salmon, and John Dorband from the ESDCD; Christopher Bock, Benjamin Kobler, Gail McConaughy, Michael Seablom, Jeffrey Smith, Stephen Talabac, and Walter Truszkowski from the AETD; and Weijia Kuang from the ESD.

For information or questions contact:
esdcdnews@webserv.gsfc.nasa.gov

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771